This is your stream on drugs:

Concentrations and loads of pharmaceuticals over one year in Baltimore streams

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Pharmaceuticals in freshwater ecosystems

- Pharmaceuticals are ubiquitous in freshwater systems

- They can disrupt physiological and ecological processes even at low concentrations

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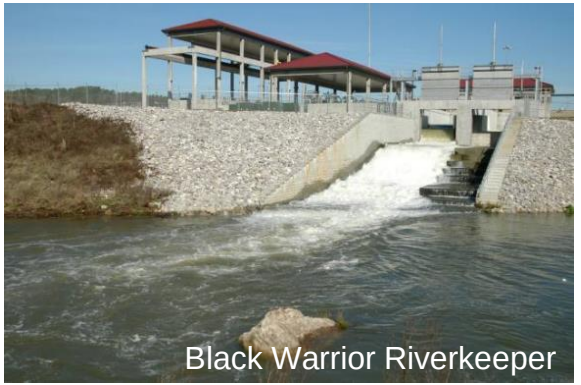
- Pharmaceuticals are ubiquitous in freshwater systems
- They can disrupt physiological and ecological processes even at low concentrations
- Effluent from wastewater treatment plants (WWTPs) is a well-known source of pharmaceutical pollution



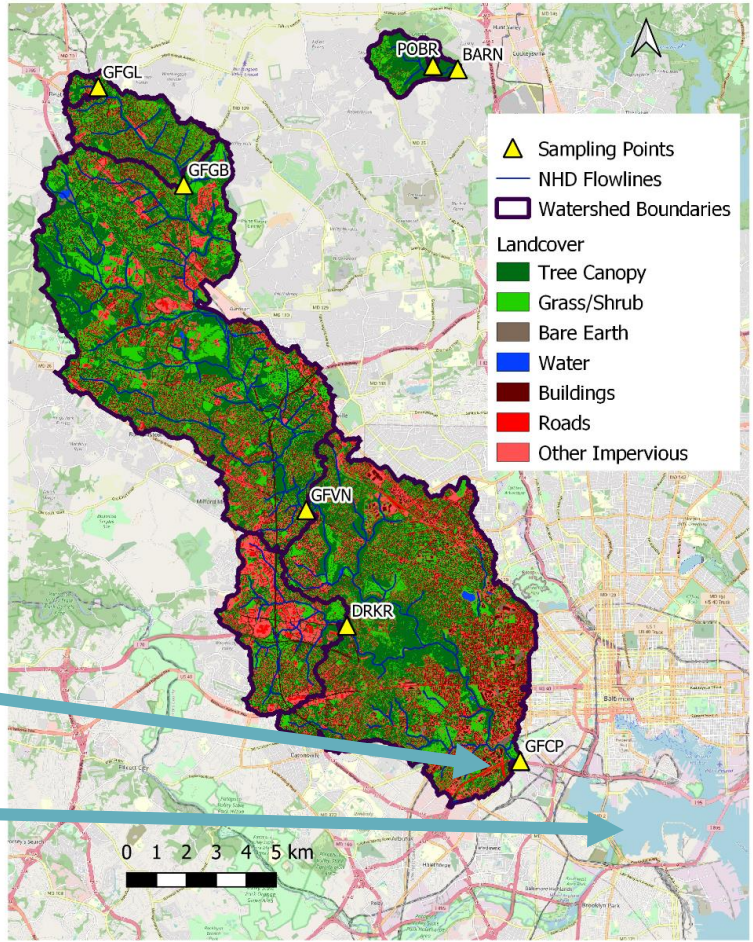
What are pharmaceutical loads in urban streams that don’t receive treated effluent, and what are the major sources?

The data

One year of weekly water samples from a watershed in Baltimore, MD with no WWTP effluent

- 92 target pharmaceutical compounds

USGS streamflow data (5 min)



Watershed outlet

Chesapeake Bay

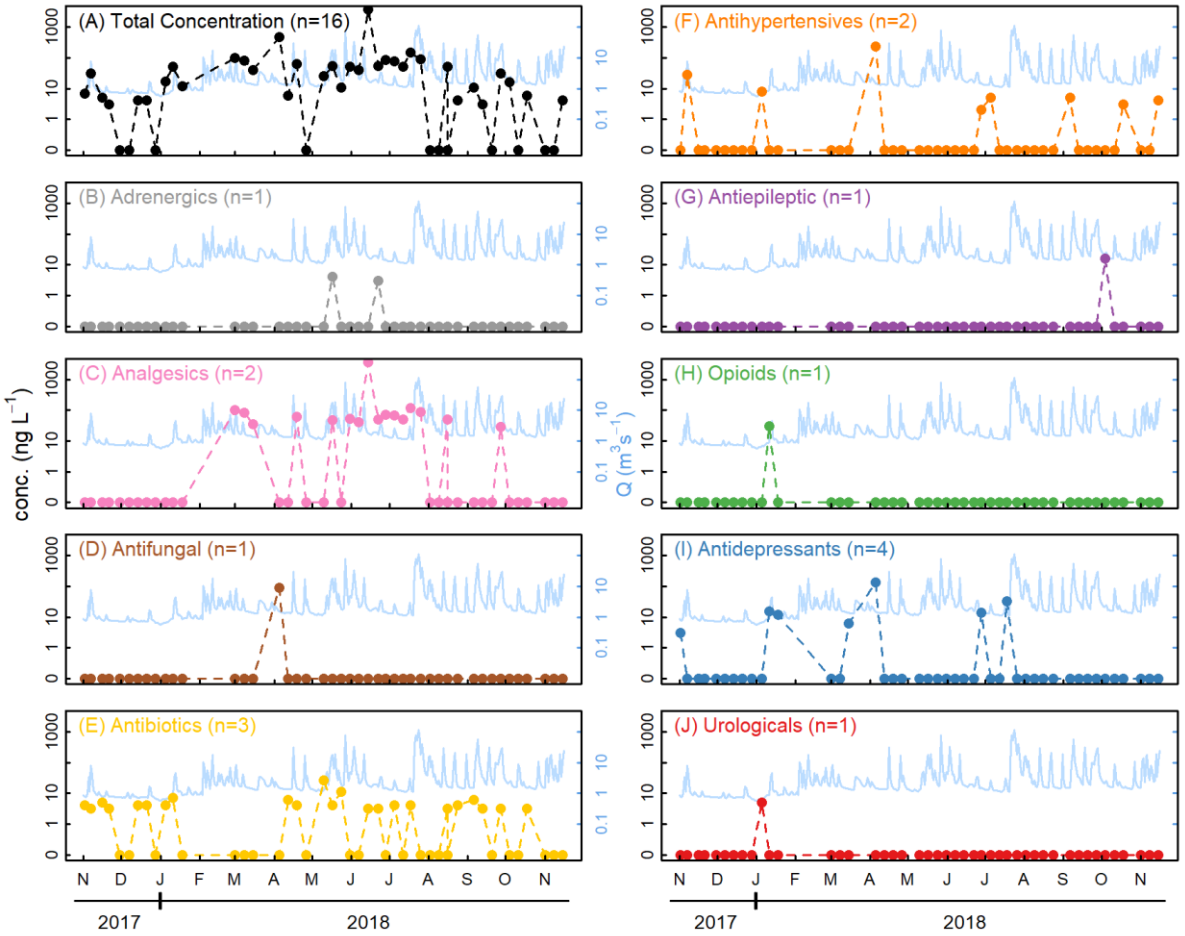
The data

Over one year of weekly monitoring (Nov 2017- Nov 2018), we detected 16 different pharmaceuticals from 9 classes

- Most commonly detected: **trimethoprim** (an antibiotic), detected in **21 of 46 samples**

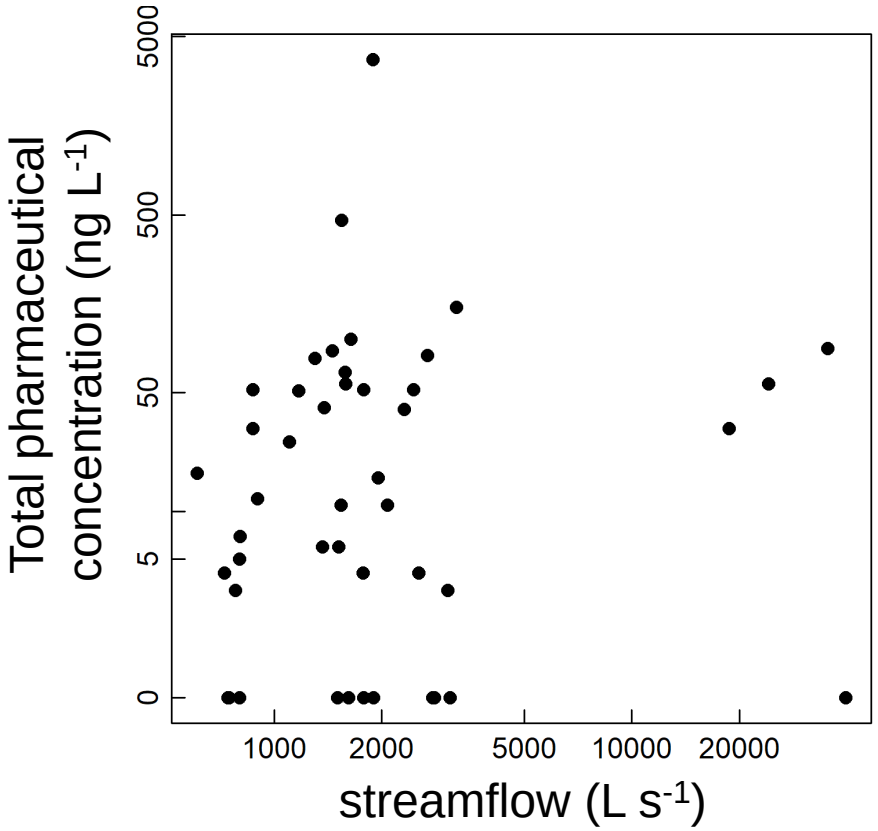
- Highest concentration detected: **acetaminophen** (an analgesic), **3717 ng L^{-1}**

Concentrations were highly variable over time



Data below level of quantification plotted as zero

Pharmaceutical concentration vs. streamflow:



Questions:

- What is the annual load of pharmaceuticals in an urban stream that does not receive WWTP effluent?
- What are the likely sources of pharmaceuticals to Gwynns Falls?

So how do we determine load, given:

Many observations below level of quantification?

Lack of clear relationship between concentration and streamflow?

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Many observations below level of quantification?

Lack of clear relationship between concentration and streamflow?

Examine potential extremes to get estimates that likely bracket the load.

Methods for calculating annual load

Many observations below level of quantification?

Samples below LoQ assumed to be:

1. The compound is absent (0 ng/L)
2. Compound present below detection (1/2 of LoQ)

Lack of clear relationship between concentration and streamflow?

Methods for calculating annual load

Many observations below level of quantification?

Samples below LoQ assumed to be:

1. The compound is absent (0 ng/L)
2. Compound present below detection (1/2 of LoQ)

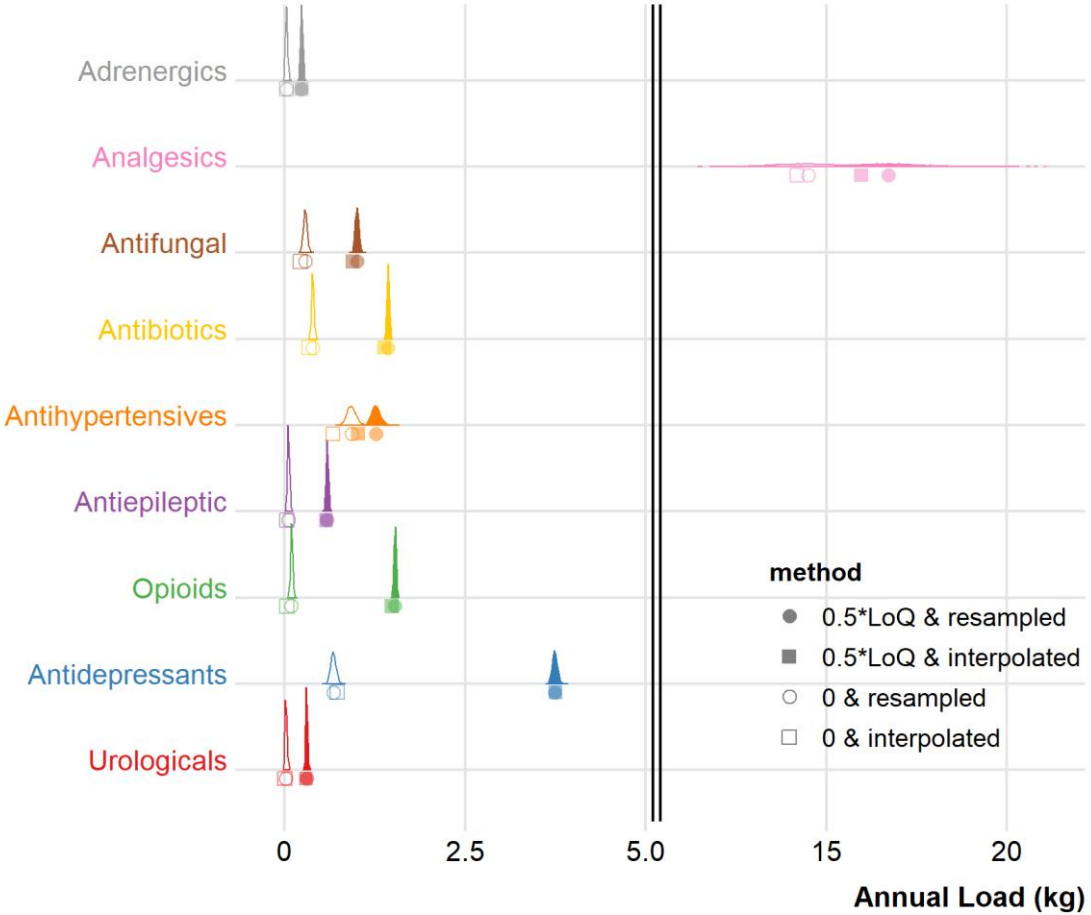
X

Lack of clear relationship between concentration and streamflow?

Concentrations between weekly samples:

A. No temporal autocorrelation, randomly taken from observed concentrations, or
B. Linear interpolation between observed concentrations

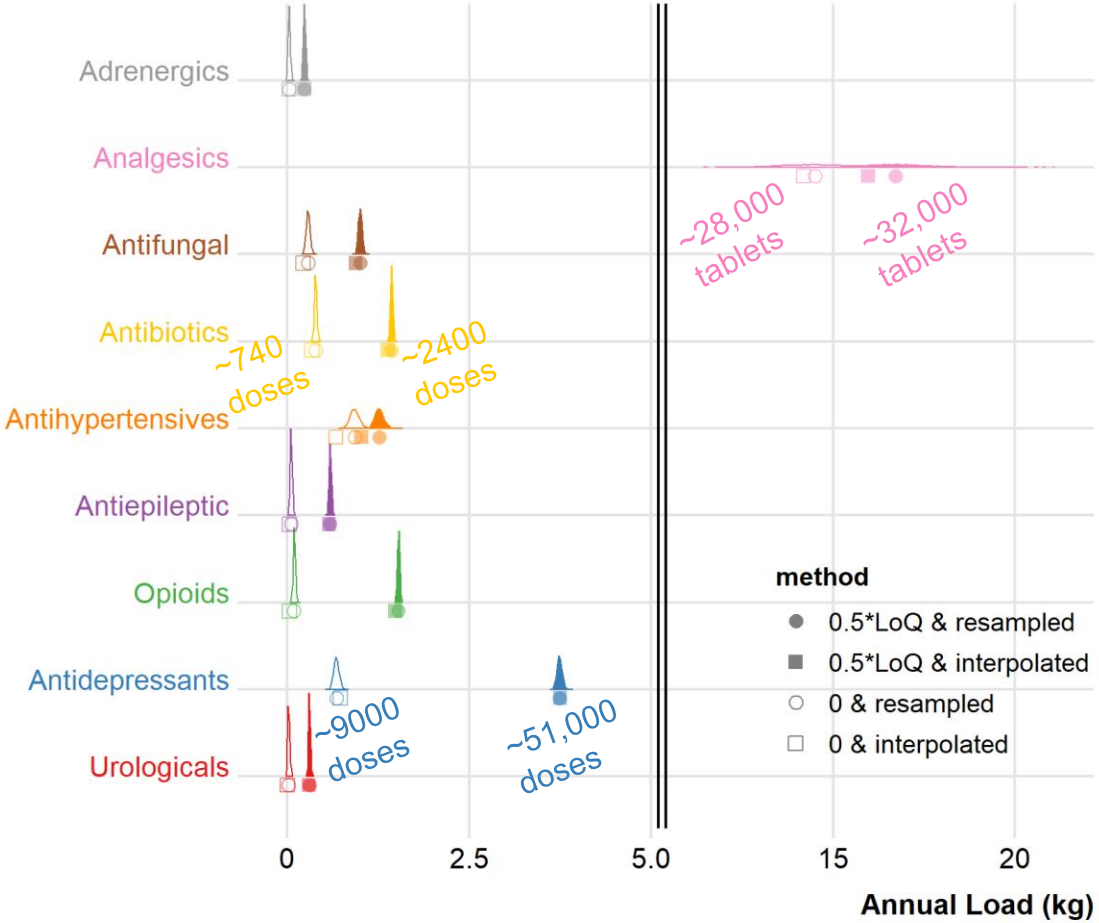
Annual loads



Fill/no fill:
Low concentrations

Circle/square:
Estimating between weekly samples

Annual loads in context: How many doses?



Fill/no fill:
Low concentrations

Circle/square:
Estimating between weekly samples

Why load?

Looking upstream: identify sources/pathways by which pharmaceuticals enter streams

Looking downstream: estimate the ecological risk for receiving waters

Questions:

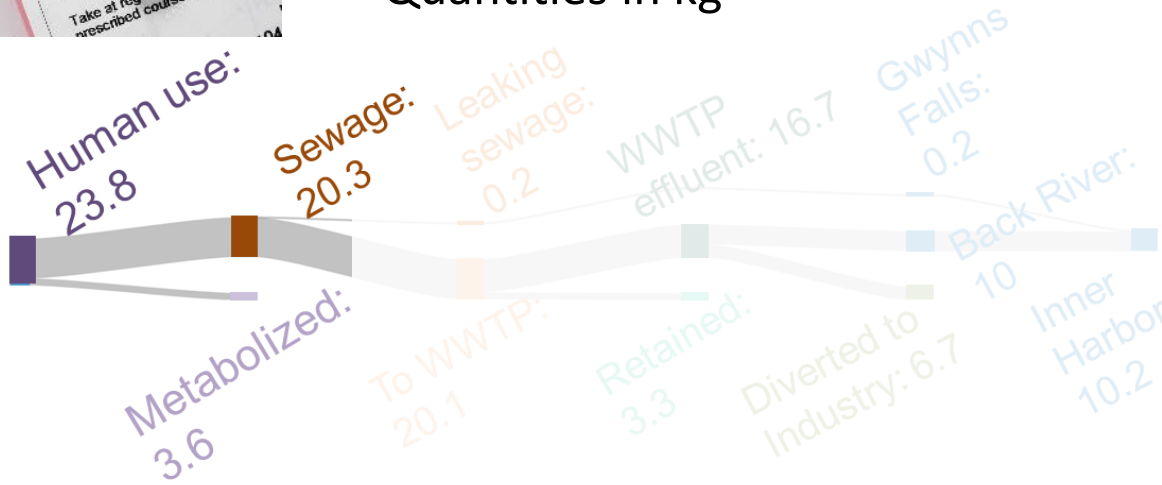
- ✓ What is the annual load of pharmaceuticals in an urban stream that does not receive WWTP effluent?

- What are the likely sources of pharmaceuticals to Gwynns Falls?

Mass balance of pharmaceuticals in Gwynns Falls watershed

(antibiotic)

Quantities in kg



1. Verlicchi et al. 2012 Sci. Total Env.
2. USEPA 2002
3. Fork and Locke 2020
4. (reported on drug labels)

- Sewage: mean reported concentrations of pharmaceuticals in WWTP influent[1]*per capita sewage volumes[2]*watershed population[3]
- Human Use: back-calculated from sewage given % metabolized[4]

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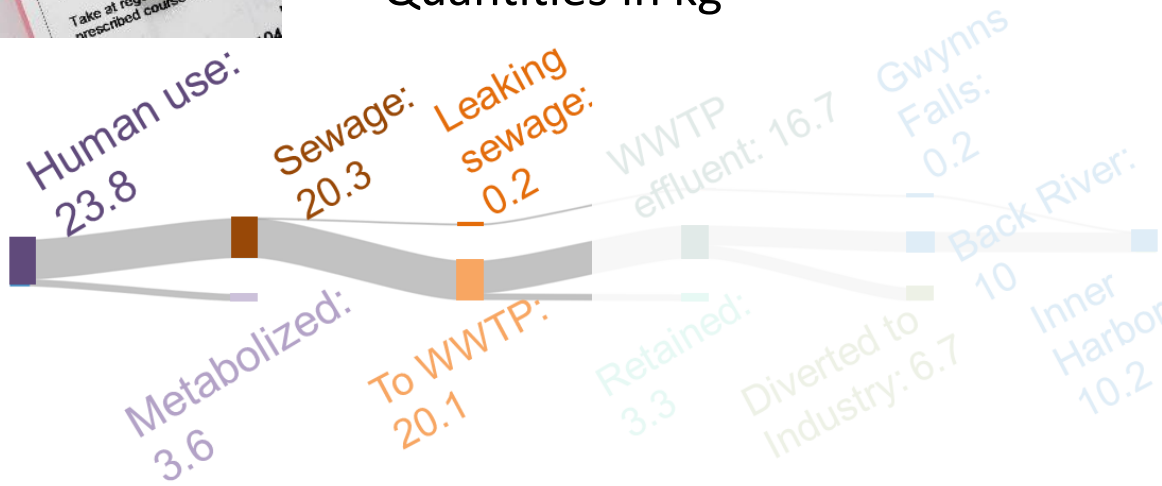

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5. Maryland Dept. of Environment

- Leaking sewage: volume of reported SSOs[5]*concentration in WWTP influent[1]

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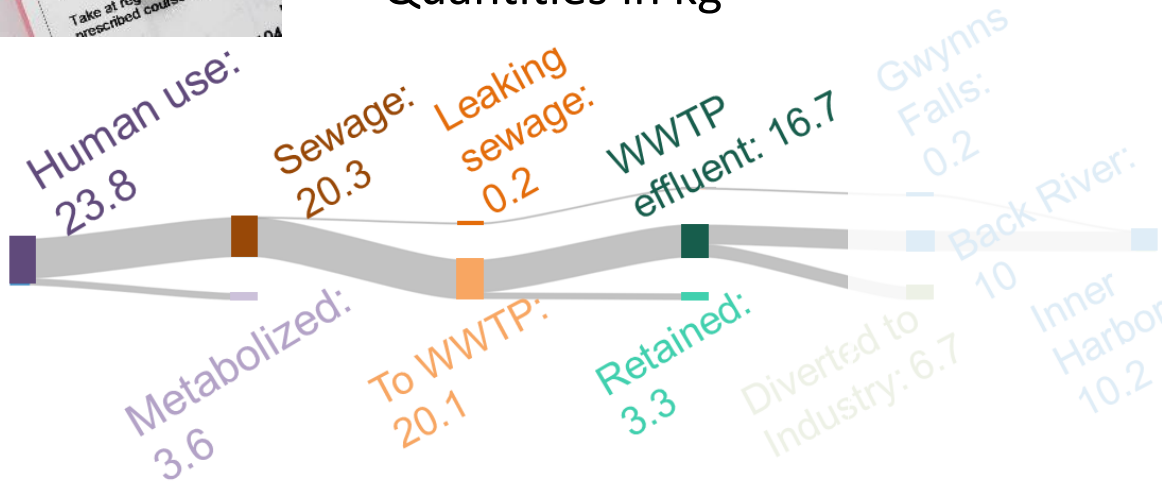

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- WWTP effluent: mean reported percentage of influent in effluent from WWTPs with similar residence time[1]*Volume to WWTP

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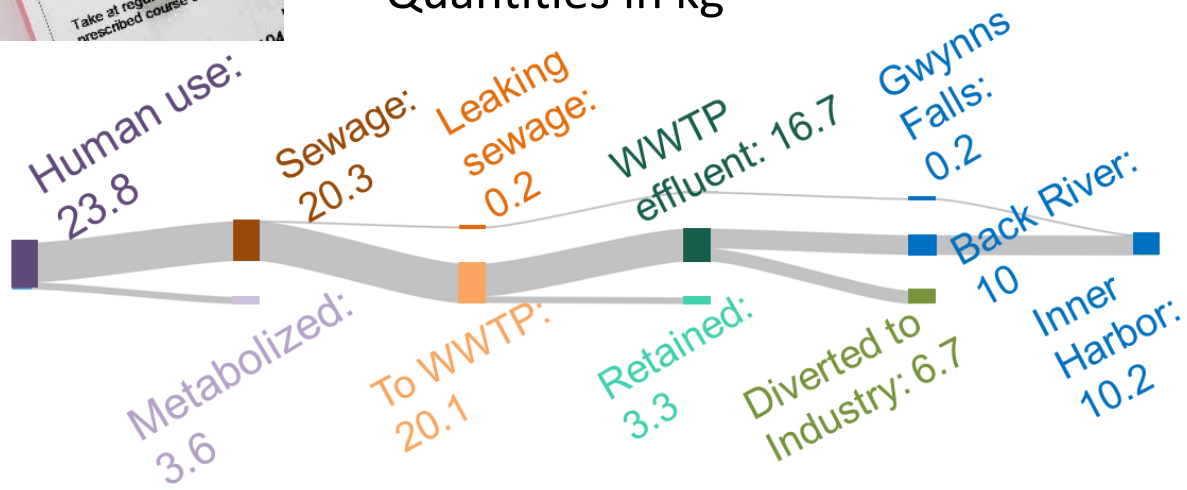

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3. Fork and Locke 2020
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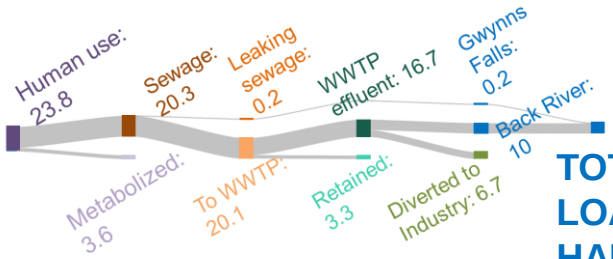
5. Maryland Dept. of Environment 2020
6. Baltimore City Dept. of Public Works 2018

- Diverted to industry: 40% of Back River WWTP effluent volume is diverted[6]

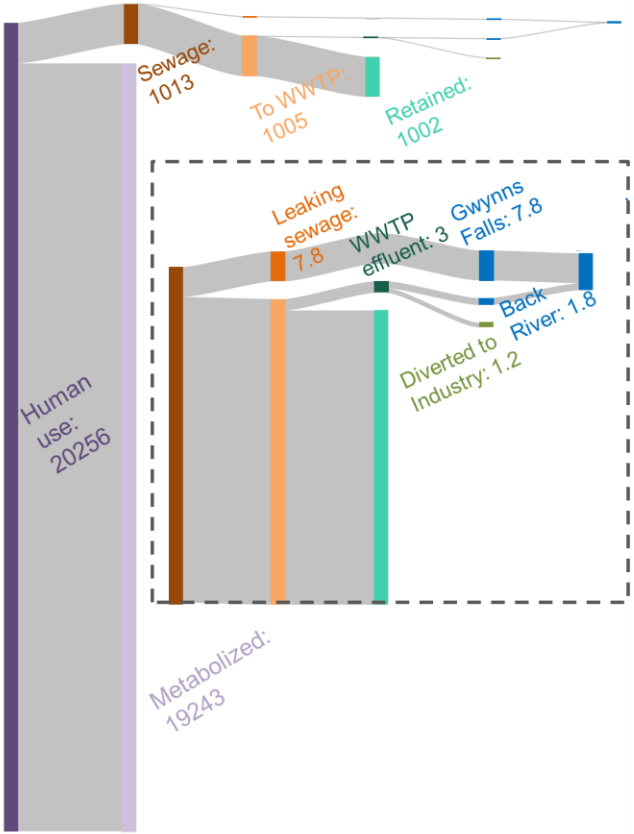
Mass balance of pharmaceuticals in Gwynns Falls watershed

(antibiotic)

(analgesic)



TOTAL LOAD TO HARBOR 10.2 kg



TOTAL LOAD TO HARBOR 9.6 kg

Takeaways:

- Leaks in aging infrastructure contribute pharmaceuticals to streams

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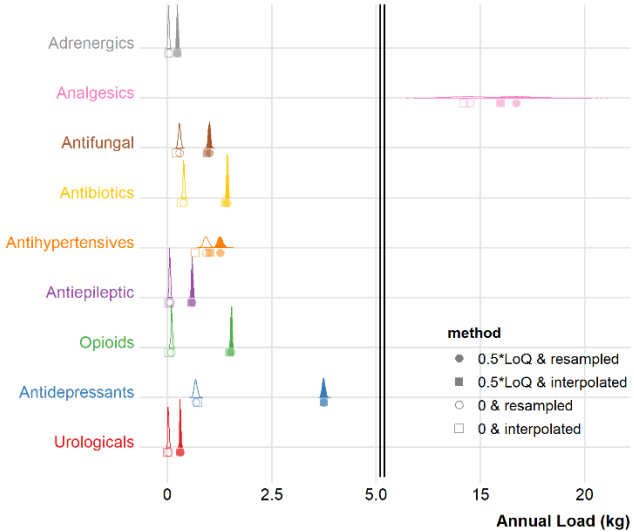
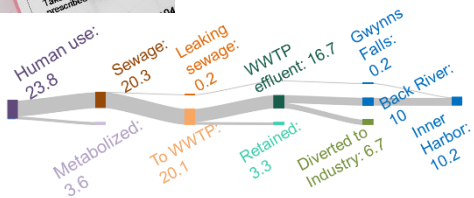
- The relative importance of sewage leaks vs. WWTP effluent as pathways to surface waters differs among pharmaceuticals

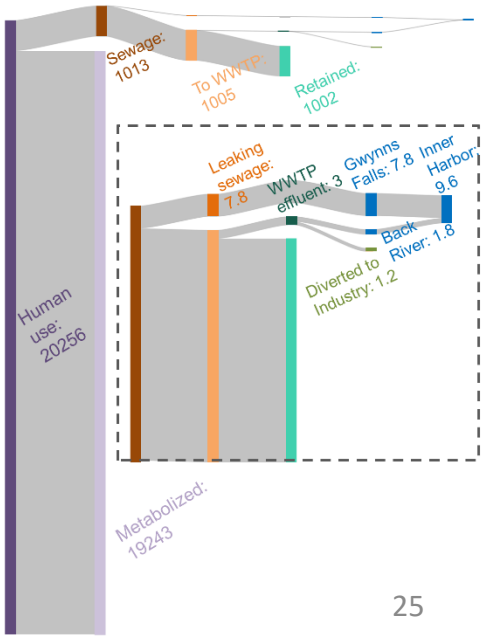
Questions?


Adrenergics
Analgesics
Antifungal
Antibiotics
Antihypertensives
Antiepileptic
Opioids
Antidepressants
Urologicals
0
2.5
5.0
15
20
Annual Load (kg)
method
0.5*LoQ & resampled
0.5*LoQ & interpolated
0 & resampled
0 & interpolated

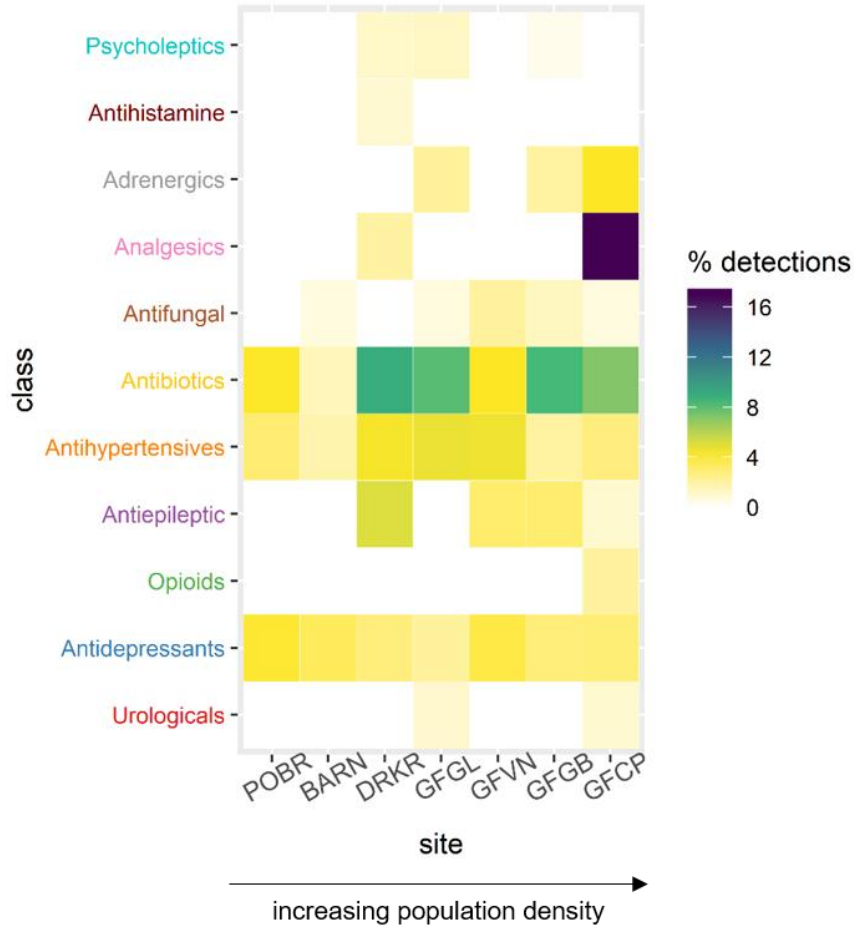

Trimethoprim
TRIMETHOPRIM 200mg
Take ONE
TWICE a day

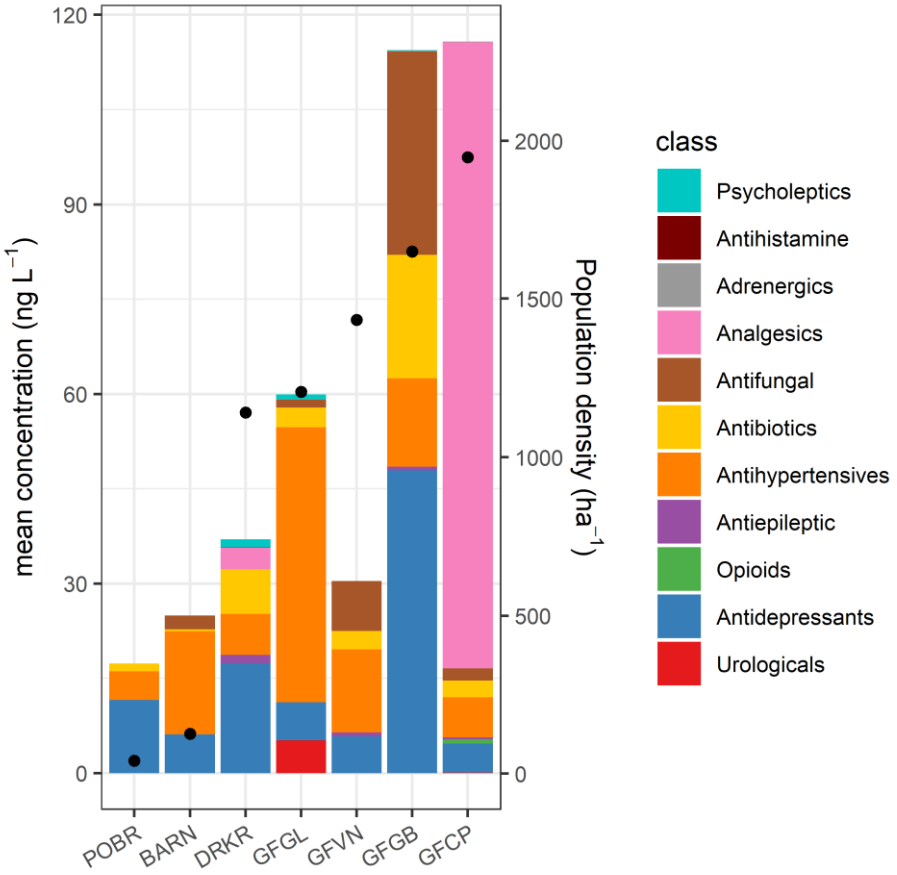

Human use: 23.8
Sewage: 20.3
Leaking sewage: 0.2
WWTP effluent: 16.7
Gwynns Falls: 0.2
Back River: 10
Inner Harbor: 10.2
Metabolized: 3.6
To WWTP: 20.1
Retained: 3.3
Diverted to Industry: 6.7


CAPLETS
ACETAMINOPHEN


Human use: 20256
Sewage: 1013
To WWTP: 1005
Retained: 1002
Leaking sewage: 7.8
WWTP effluent: 3
Gwynns Falls: 7.8
Inner Harbor 9.6
Back River: 1.8
Diverted to Industry: 1.2
Metabolized: 19243

Patterns of concentration in space

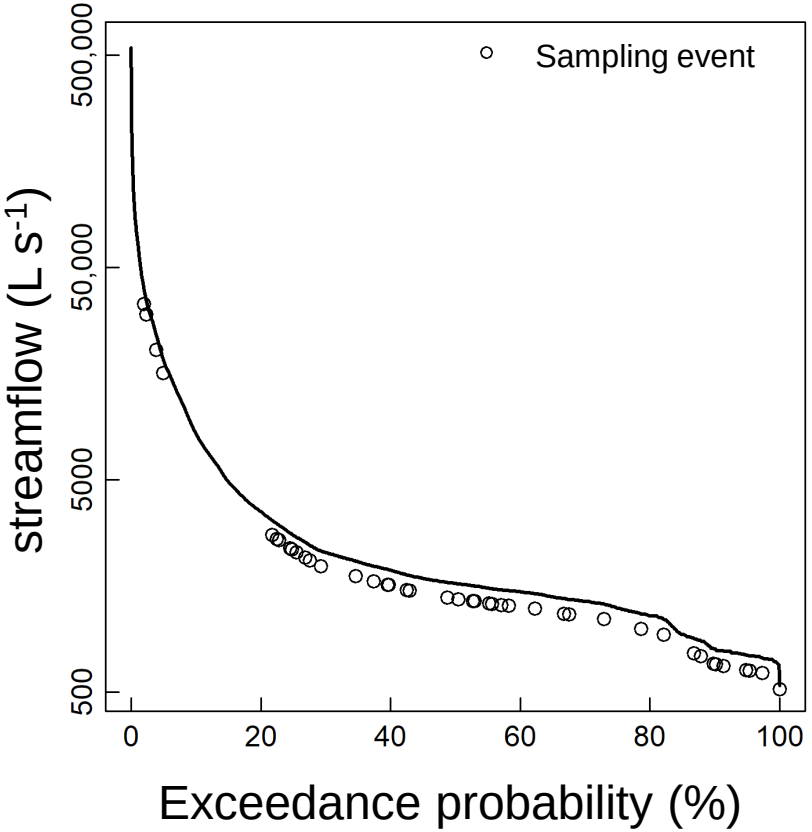




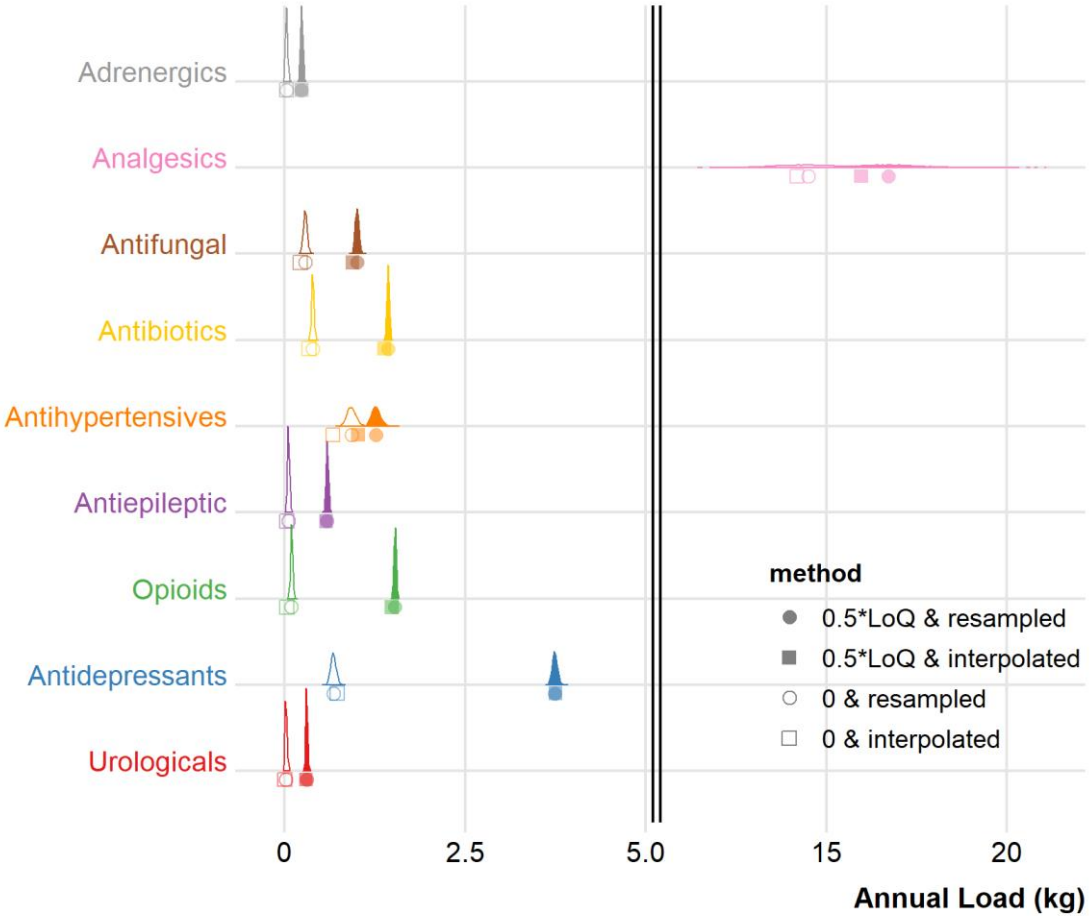
Sanitary sewer overflows:

If we compare the volume of reported SSOs to the approximate volume of sewage produced by the population, we **estimate 0.77% of sewage leaks into the river through SSOs**.

Sampling covered much of the range of flow conditions



Sources of variability in load estimates



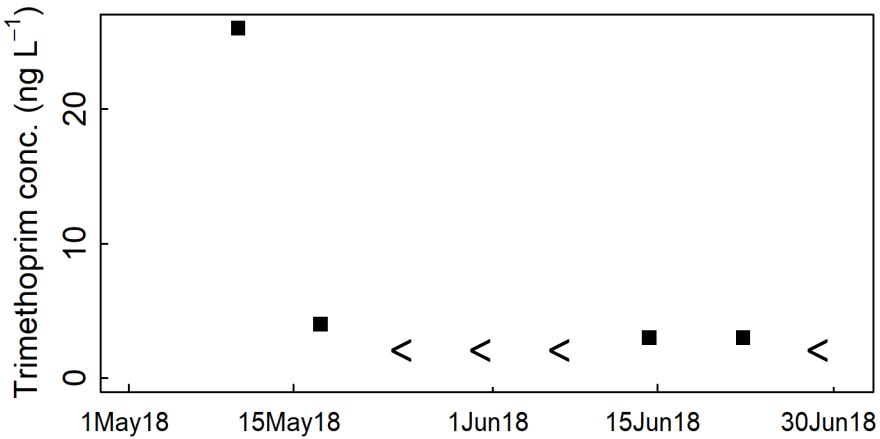
Big differences in interpolation methods (circle/square):

1. Big spread in measured concentrations

Big differences between low concentration methods (fill/no fill):

1. Lots of low values, +/or
2. Relatively high LoQ

Methods for estimating flux



Data below LoQ (“<“) assumed to be:

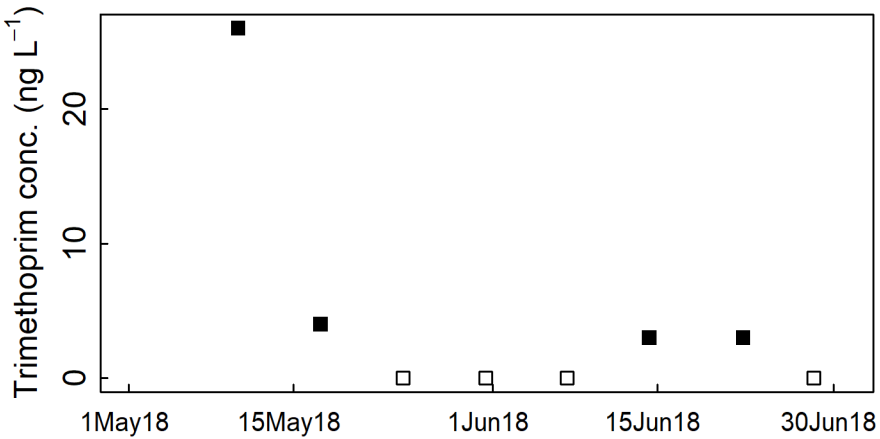
1. True zero,
2. 0.5*LoQ

X

Concentrations between weekly sampling events:

A. Resampled randomly from observed concentrations, or
B. Interpolated between observed concentrations

Methods for estimating flux



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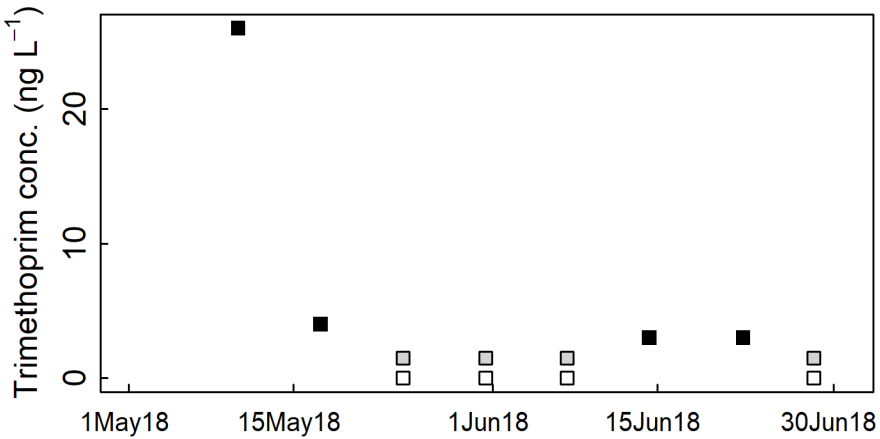

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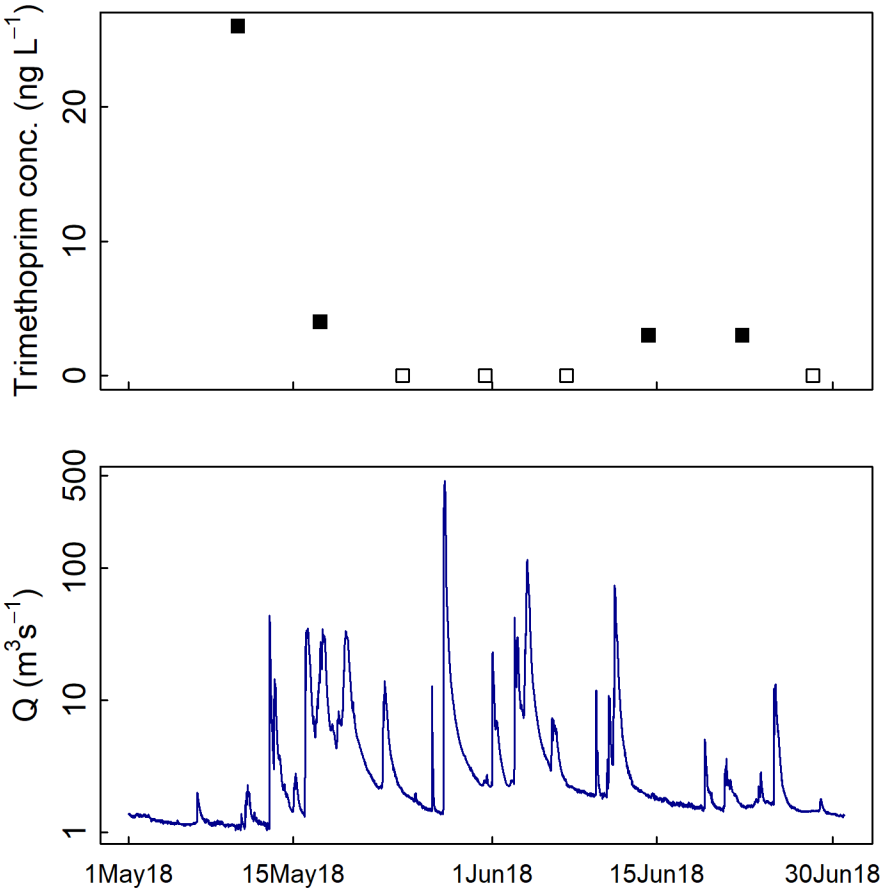

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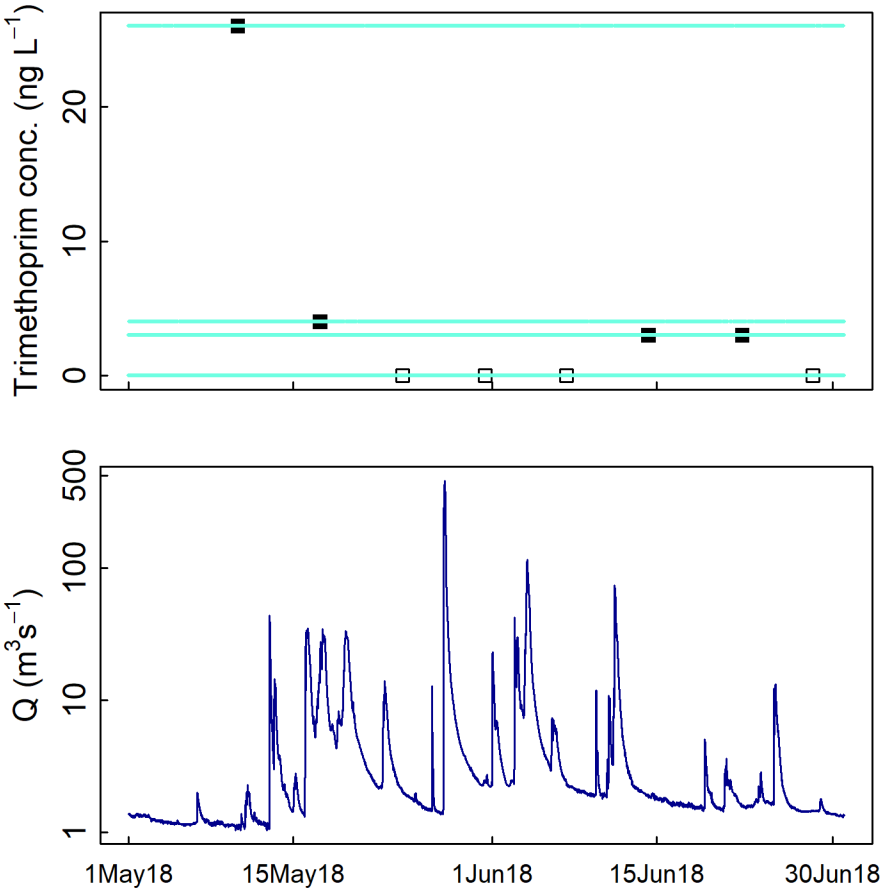

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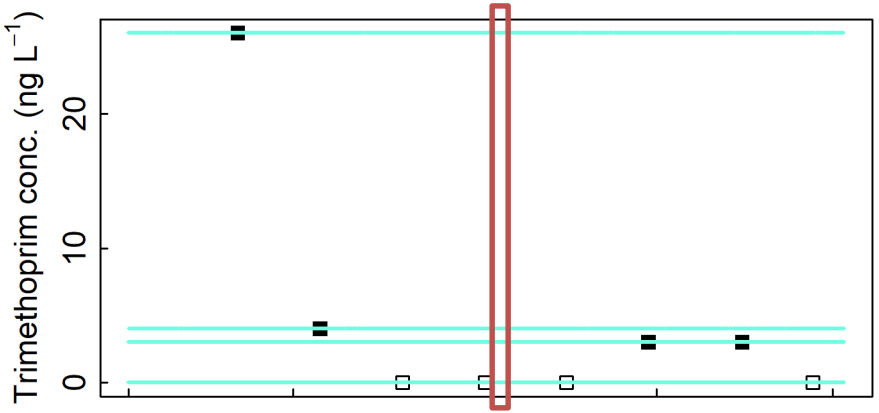

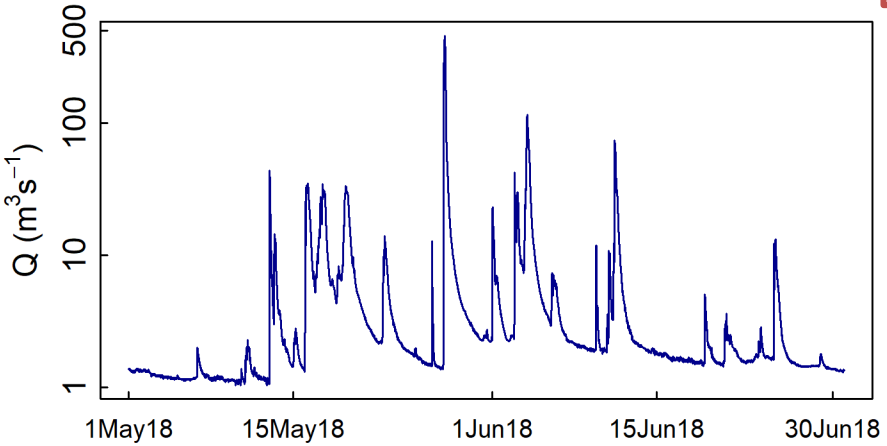

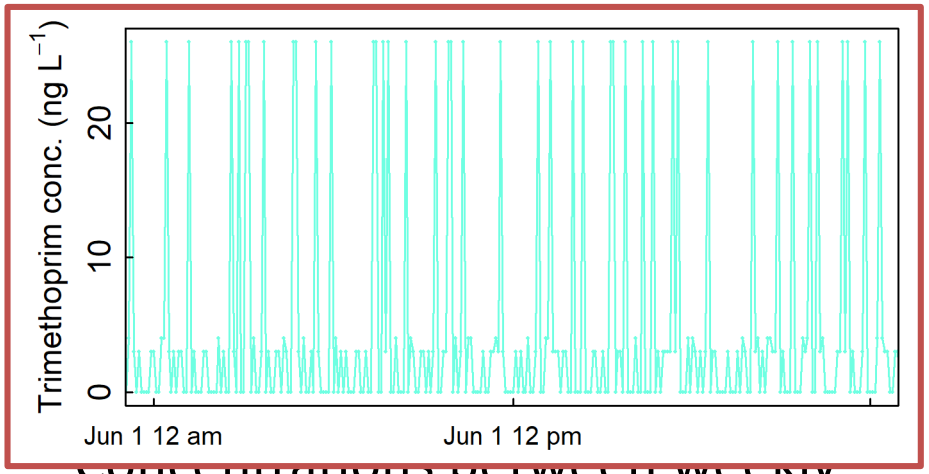

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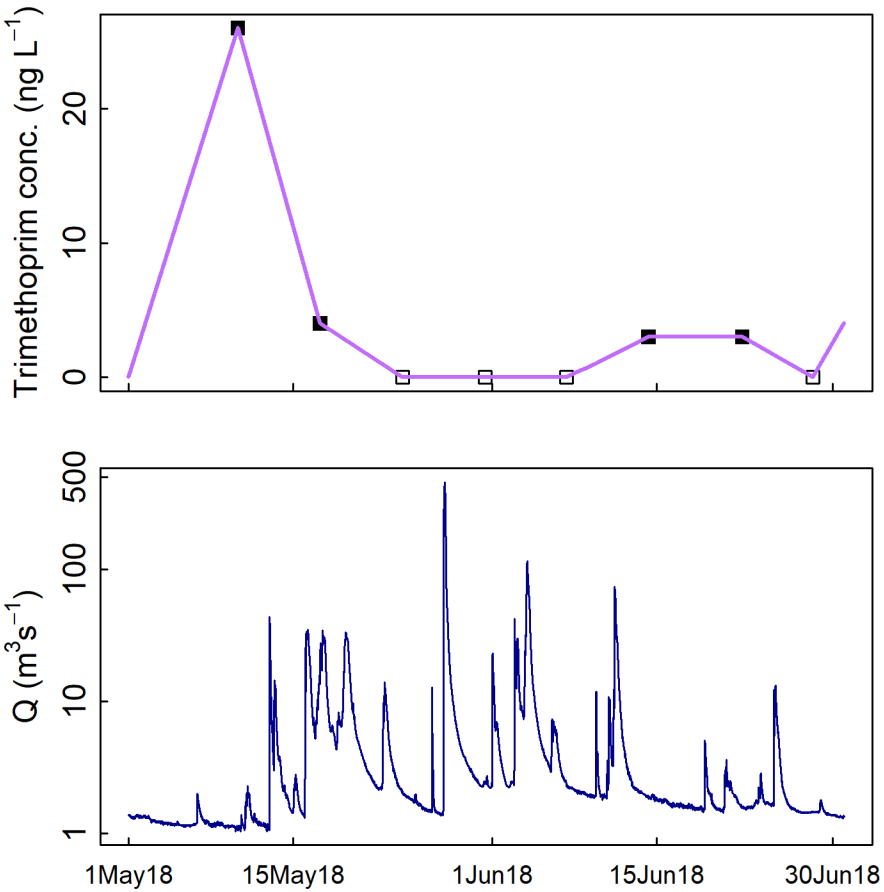

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